

Algae: The Source of Reliable, Scalable, & Sustainable Aviation Fuel

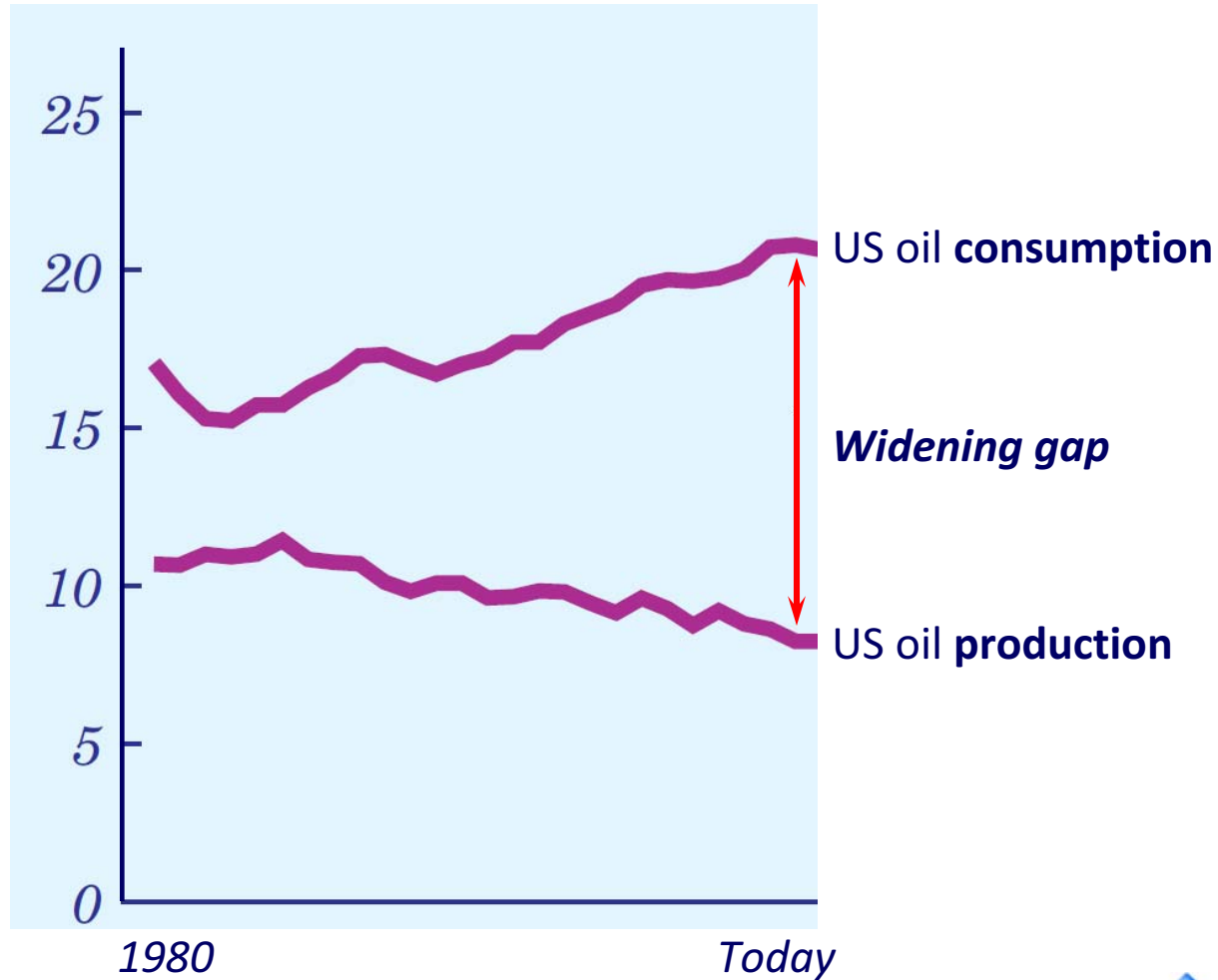
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We have an enormous, and growing, problem

Millions of barrels per day



Source: IEA 2008 Energy outlook

We make up the difference by spending billions of dollars on foreign oil

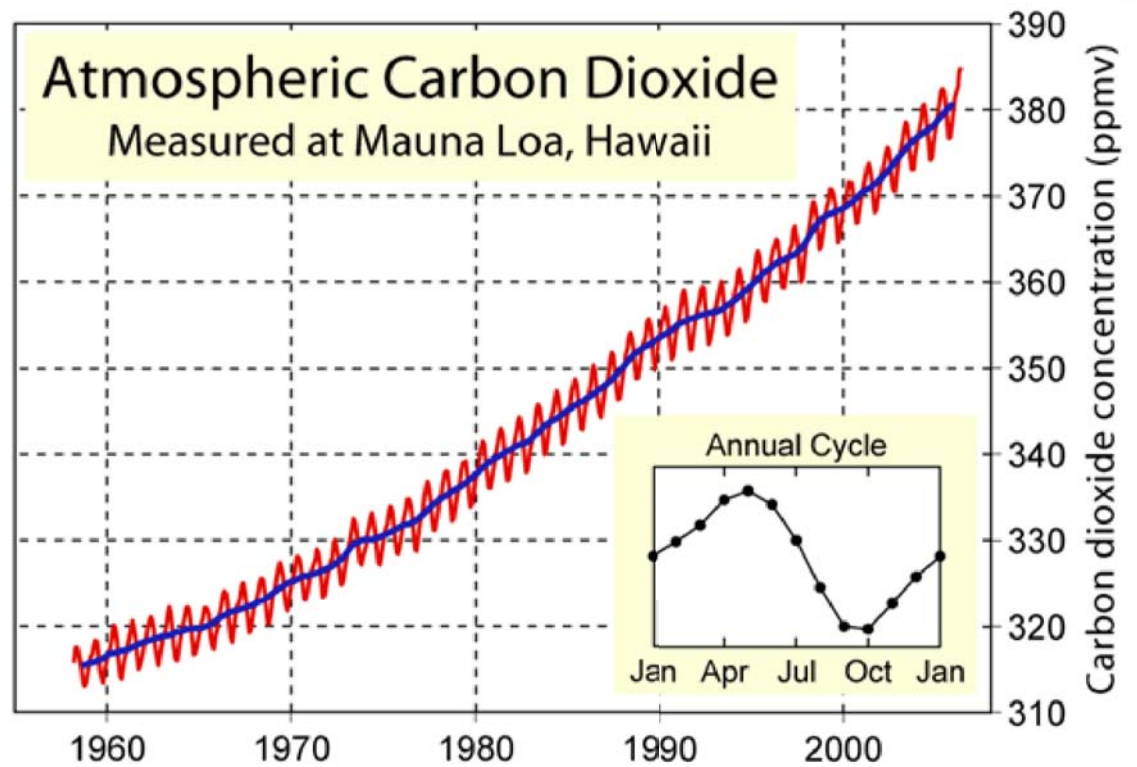
Daily US imports of crude oil	
Canada	3.2 MBD
Mexico	2.0 MBD
Venezuela	3.4 MBD
Middle East	2.9 MBD
North Africa	1.0 MBD
Asia	2.5 MBD
Russia	0.6 MBD
Off-shore EU	1.3 MBD
Total	17.0 MBD

Avg price per bbl	Total annual imports (\$billion)
\$40	\$248
\$50	\$310
\$60	\$372
\$70	\$434
\$80	\$496
\$90	\$558
\$100	\$621
\$110	\$683
\$120	\$745
\$130	\$807
\$140	\$869
\$150	\$931
\$160	\$993

And the other costs?



NOAA, 2008; David Keeling, Scripps

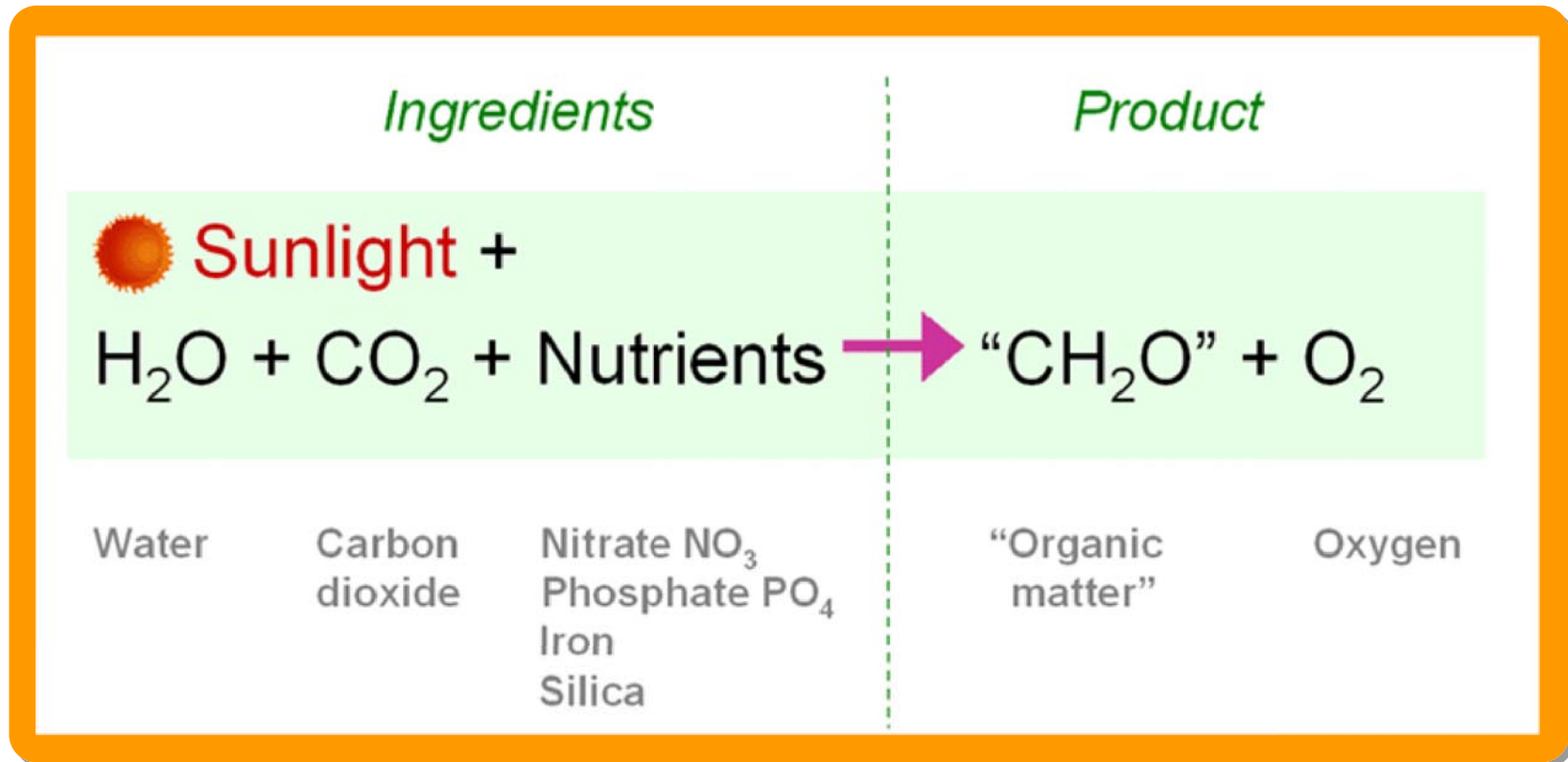


The ideal way we can fill this enormous – *and widening* – gap in liquid transportation fuels is by developing fuels which meet the following criteria

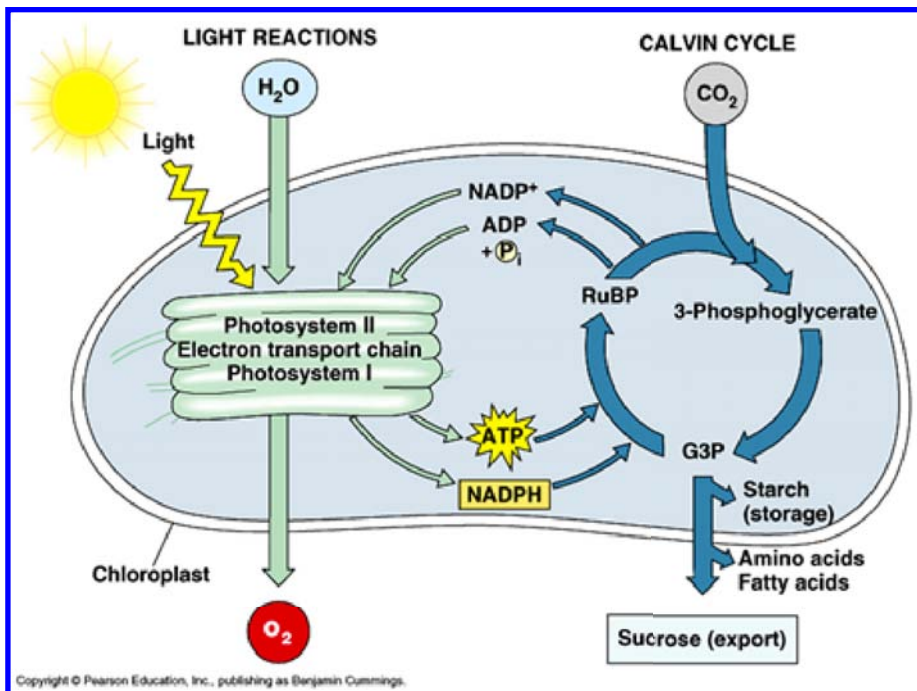
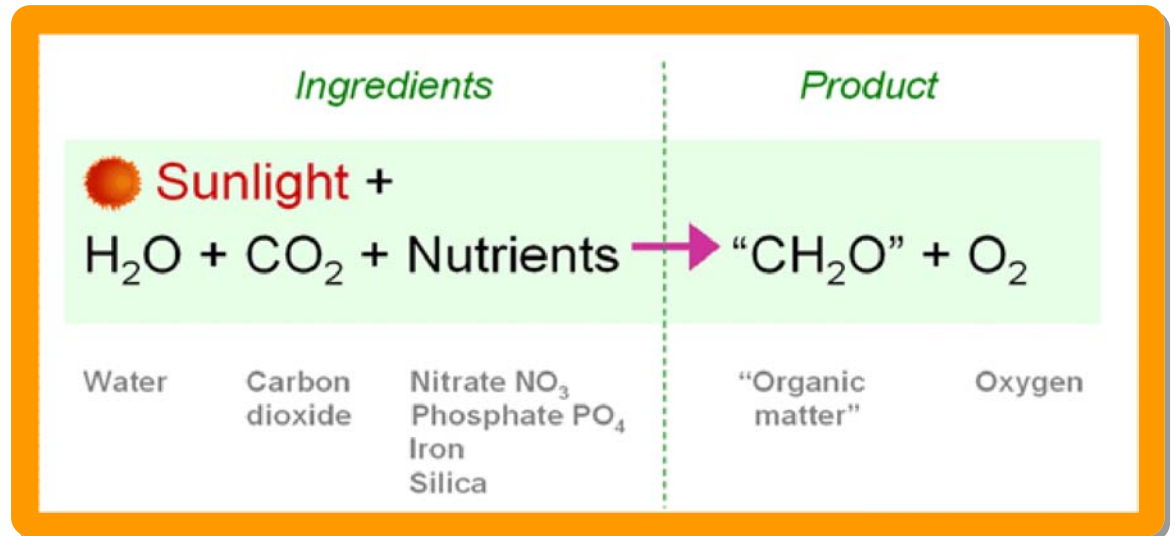
- Fuels that are **completely fungible** (100% “drop in solutions”) with
 - Existing oil and fuel movement infrastructure (e.g., pipelines, terminals)
 - Existing fleet of land and air vehicles (i.e., cars, trucks, jets)
 - Existing refining infrastructure
- Fuels that **do not compete** with agricultural products, agricultural land, or fresh water
- Fuels that have a **favorable life cycle** with respect to CO₂ compared to conventional petroleum
- Fuels that **can be scaled** to well over 1,000,000 barrels per day to meaningfully impact the widening gap between US fuel production and consumption

Why Algae?

The most important chemical reaction on our planet



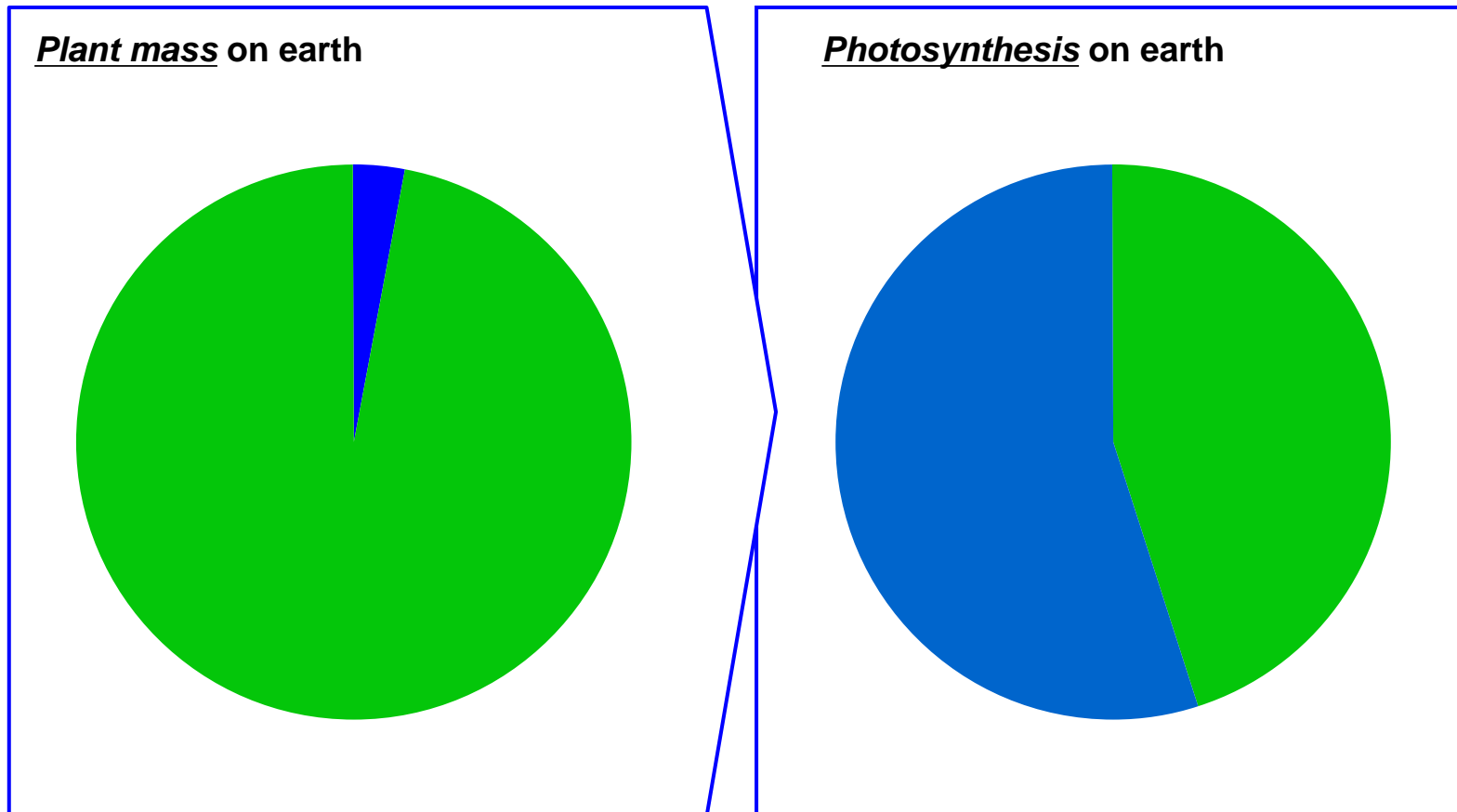
The most important chemical reaction on our planet was tailor made for algae



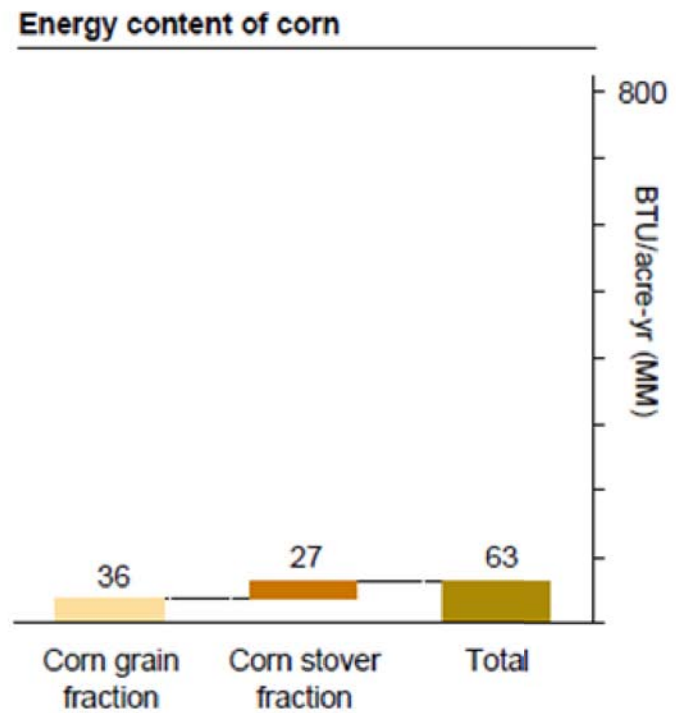
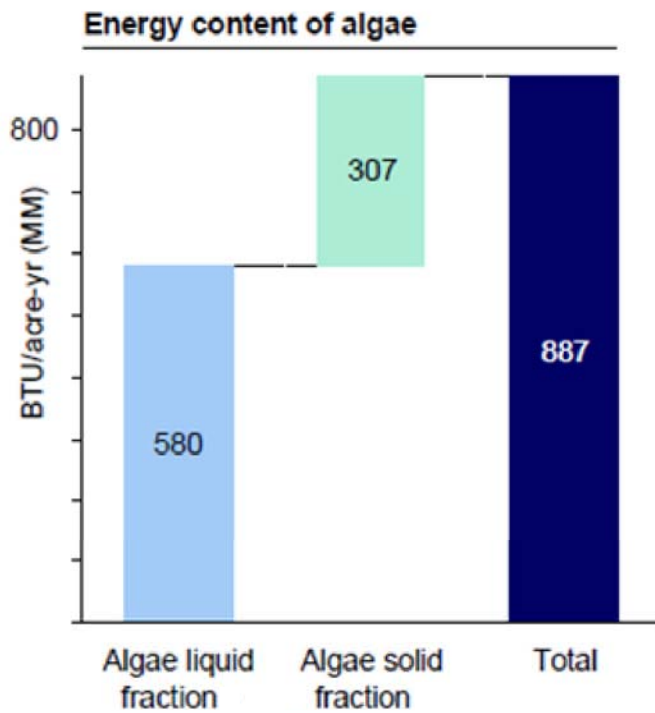
- Nearly all of the biomass of algae is concentrated in the chloroplast – the engine that turns sunlight and CO₂ into organic carbon (i.e., C-C and C-H bonds)
- Algae “waste” no time or energy making stalks, roots, leaves, or fruit
- The result is maximum hydrocarbon per unit area

Algal oil production dwarfs that of all terrestrial plants because of the enormous advantage they have converting CO₂ to hydrocarbons

- Aquatic plants
- Terrestrial plants



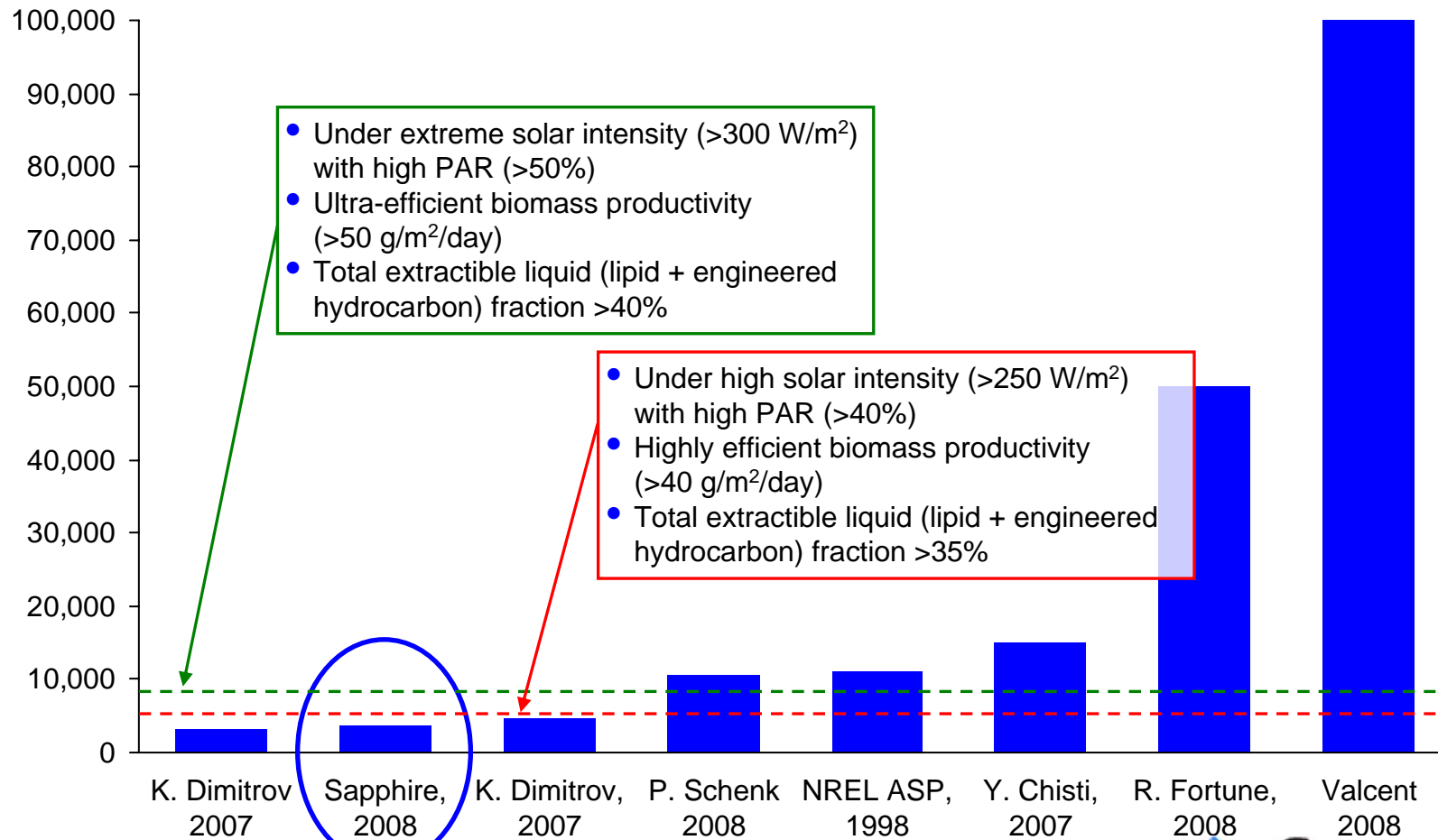
Algae are 40x more efficient at converting sunlight to hydrocarbon than terrestrial plants



There is no shortage of estimates for how much oil an acre algae can yield per year...

Current estimates of annual oil production per acre of cultivated algae
Gallons per year

--- Best case by 2020
--- Base case by 2020



- Under extreme solar intensity (>300 W/m²) with high PAR (>50%)
- Ultra-efficient biomass productivity (>50 g/m²/day)
- Total extractable liquid (lipid + engineered hydrocarbon) fraction >40%

- Under high solar intensity (>250 W/m²) with high PAR (>40%)
- Highly efficient biomass productivity (>40 g/m²/day)
- Total extractable liquid (lipid + engineered hydrocarbon) fraction >35%



...but even with the most conservative estimates, extraordinary yields are likely

A highly efficient conversion of solar energy...

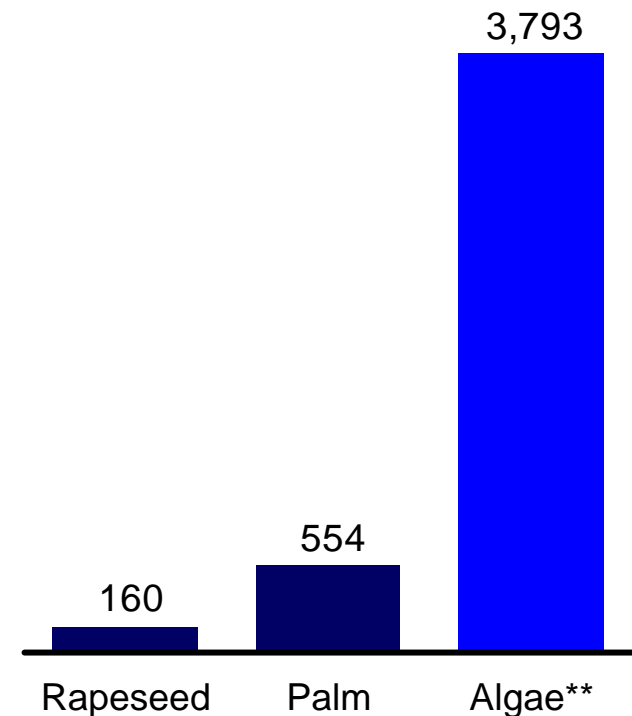
Solar irradiation	100%
Photosynthetic active radiation (PAR)	40%
Entering the water body	75%
Max efficiency of photosynthesis	25%

Theoretically maximum PE 8% of total irradiation

Target PE for conversion of sunlight to hydrocarbon* 1.9 – 3.8% of total irradiation

...Leads to high yields of oil

Oil yield
Gal per acre per year



* Assuming 25-50% of theoretical maximum PE is achievable

** Yield at 30 g/m²/day (Medium irradiation); 30% oil content

The implications of (even conservative) oil yields are dramatic

	Current trajectory	Base case, 2020	Best case, 2020
	3,800	5,000	8,000
Entire USAF jet fuel consumption (200,000 bpd)	800,000 acres 35x35 miles	600,000 acres 31x31 miles	400,000 acres 25x25 miles
5% of US consumption (1,000,000 bpd)	4 MM acres 80x80 miles	3 MM acres 70x70 miles	2 MM acres 55x55 miles
10% of US consumption (2,000,000 bpd)	8 MM acres 112x112 miles	6 MM acres 97x97 miles	4 MM acres 80x80 miles
25% of US consumption (5,000,000 bpd)	20 MM acres 180x180 miles	15 MM acres 150x150 miles	10 MM acres 125x125 miles
50% of US consumption (10,000,000 bpd)	40 MM acres 250x250 miles	30 MM acres 215x215 miles	20 MM acres 175x175 miles
4% of US consumption by volume* (800,000 bpd equivalent)		23 MM acres** 190x190 miles	

Gallons oil per acre per year

Total US oil production, including off-shore and arctic is 5 million bpd

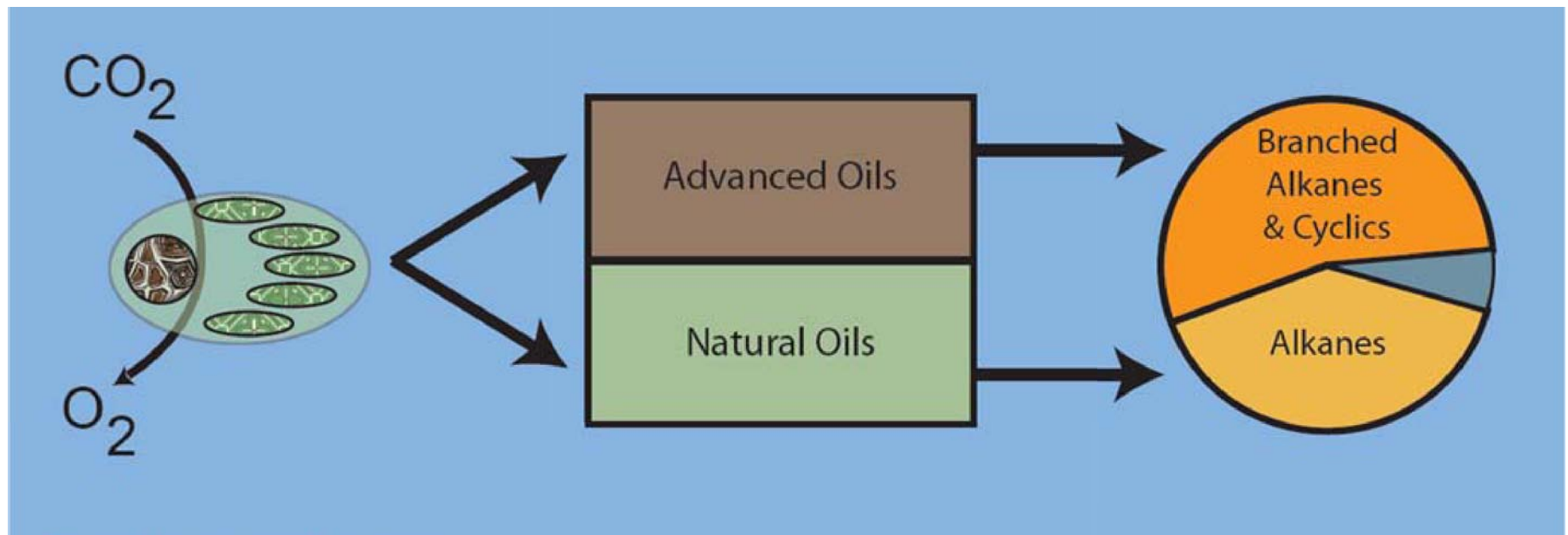
Productivity of corn for ethanol – 25% of corn growing land was used to make ethanol to displace 4% of US fuel

* 3% Based on energy content. Numbers based on 2007 production figures from USDA, Greencarcongress



Carbon Neutral, Renewable transportation fuel of the future

Sunlight + CO₂ = Aviation Fuel



**Sapphire Production
Platform**

Green Crude

Aviation Fuel

Biology and Engineering = CO₂ Neutral, Renewable Fuels

- Nothing in modern agriculture would be where it is today without thousands of years of directed evolution and, ultimately, genetic engineering



- With energy crops like algae we gain the benefits of science and engineering
- Without the luxury of thousands of years to direct the evolution of algae, the only solution for commercial scale is genetic engineering

Rapid Developments



Algae Jet Fuel made in partnership with





<http://www.sapphireenergy.com/mediacenter>



Sapphire Energy Overview and Accomplishments

- Leaders in development of green crude from algae
- HQ San Diego, Development facilities Las Cruces New Mexico
- Team is best in class in biotechnology, algal production, civil engineering, biorefining, biofuels, and business development
- First algal feedstock refined to green gasoline, green diesel, and green jet fuel
- First commercial aircraft flight using algal fuel -- January 7, 2009, Continental Airlines
- Largest cultivation of enhanced algal strains
- Dominant IP portfolio, with over 200 patents in algal fuel space
- Raised over \$100 million from top tier investors
- 90+ employees

